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EUROPEAN PATENT APPLICATION

⑰ Application number: 82102188.8

⑤① Int. Cl.²: **A 61 M 1/03, F 04 D 13/02,**
H 02 K 7/09

⑳ Date of filing: 17.03.82

③① Priority: 18.03.81 US 245007

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④③ Date of publication of application: 22.09.82
Bulletin 82/38

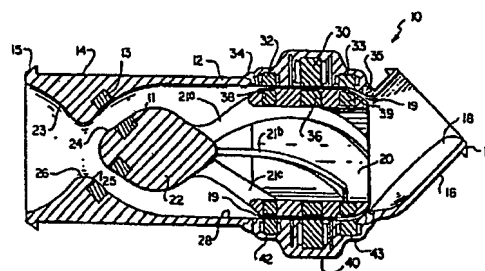
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⑧④ Designated Contracting States: **CH DE FR GB IT LI SE**

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⑤④ **Magnetically suspended and rotated impellor pump apparatus and method.**

⑤⑦ A novel pump apparatus and method, the pump (10) including a magnetically suspended and rotated impellor (20) inside the pump housing (12). A novel sensor system (34, 35) detects the position of the impellor (20) and thus provides the necessary information for operation of a suspension circuit for magnetically suspending the impellor (20). A valve member (22) may be included as part of the impellor (20) to prevent reverse flow in the event of impellor failure when used as a ventricular assist device.



EP 0 060 569 A1

1 MAGNETICALLY SUSPENDED AND ROTATED
2 IMPELLOR PUMP APPARATUS AND METHOD
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4 Background

5 1. Field of the Invention

6 This invention relates to pumps and, more particu-
7 larly, to a novel pump apparatus and method, the pump
8 including a magnetically suspended and rotated impellor.

9 2. The Prior Art

10 Historically, fluids are pumped by a variety of pump
11 apparatus including, for example, positive displacement
12 pumps such as piston-type pumps, moving diaphragm pumps,
13 peristaltic action pumps, and the like. The conventional
14 centrifugal-type pump involves a shaft-mounted impellor
15 immersed in the fluid. The shaft extends through a seal
16 and bearing apparatus to a drive mechanism. However, it
17 is well-documented that shaft seals are notoriously
18 susceptible to wear and also attack by the fluids,
19 resulting in an ultimate leakage problem.

20 It is also well known that certain special applica-
21 tions require specific pumping techniques. For example,
22 fluids such as corrosive fluids (acids or caustics) and
23 sensitive fluids such as blood, each require specialized
24 pumping techniques.
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1 The pumping of blood involves known hazards. In
2 particular, the shaft seal for an impellor-type blood
3 pump is an area of stagnation and excessive heat. These
4 events foster the formation of thrombus and provide a
5 place for bacterial growth. Seal leakage can also lead
6 to bearing freezing. Numerous attempts to avoid the
7 foregoing problems associated with pumping blood have
8 been made using flexible diaphragm and collapsible tubing
9 in roller pumps. However, the continual flexing of the
10 diaphragm and/or the tubing material is known to (1)
11 change the blood-contacting properties of the material,
12 (2) result in material fatigue with the attendant risk of
13 an eventual rupture, and (3) dislodge fragments of the
14 internal wall of the flexible material causing the
15 fragments to pass as emboli into the bloodstream.

16 Studies have been made of pumps used as total arti-
17 ficial hearts implanted in experimental animals. These
18 studies have continued for the past 20 years. These
19 pumps can be categorized as producing pulsatile or
20 nonpulsatile flows. Pulsatile pumps universally require
21 valves (mechanical or tissue) with their inherent
22 problems and limitations. While the nonpulsatile pumps
23 generally do not require valve systems, they do require
24 rotating shafts passing through bearings and seals with
25 the inherent problems set forth hereinbefore. Most of
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1 these systems (non-pulsatile) have been implanted outside
2 of the body for short-term cardiac assistance and have
3 experienced a moderate degree of success.

4 Historically, the pump mechanism of these total
5 artificial hearts have been energized with gases
6 (pneumatic systems), electricity (motors, solenoids,
7 etc.), nuclear energy, and skeletal muscles. The energy
8 sources and their convertor systems possess additional
9 components that increase the complexity of the total
10 systems and thereby contribute to the overall
11 unreliability of the systems. Also, the energy
12 conversion system must be correlated and integrated into
13 the pump design and the total design must be configured
14 to fit within the available anatomical space. Other
15 drawbacks include (1) high-bulk characteristics, (2)
16 dependence on external pneumatic systems, (3) choice of
17 available materials for fabrication, and (4) multiple
18 bearings and moving parts with inherent limitations in
19 the tested and predicted life expectancies of the same.
20 Most prior art systems inherently have excessively high
21 (1) noise characteristics, (2) vibration, and (3) recoil
22 (thrust) levels.

23 The current state of the art for blood pumps is
24 being developed in at least four laboratories in the
25 United States. Survival times for calves with total
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1 artificial heart replacements of about five months have
2 been experimentally achieved with the longest living
3 about seven months. The natural ventricles of a man have
4 been replaced at least once by a total artificial heart
5 in one reported incident as early as 1969.

6 One of the inventors has been closely associated
7 with animal experiments involving both total artificial
8 hearts and ventricular assist devices for at least seven
9 years. As a result, he has held most of the survival
10 records obtained with calves having the total artificial
11 heart. These records include at least 38 days for an
12 electromechanical system and 221 days for a pneumatic
13 system. Accordingly, this inventor is very familiar with
14 current research in total artificial hearts and assist
15 devices throughout the world and is thus cognizant of the
16 many problems and limitations with the current state of
17 the art blood pumps. For example, United States Letters
18 Patent No. 3,641,591 involves a flexing diaphragm that
19 limits the material selection and requires a portable
20 energy supply. U. S. Patent Nos. 3,633,217 and 3,733,616
21 are electro-magnetically activated and involve flexing
22 diaphragms, mechanical linkages, with a corresponding
23 increased weight and bulk. U. S. Patent No. 3,896,501 is
24 an electro-mechanical device having a complexity of
25 gears, shafts, and bearings with the attendant problems

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1 set forth hereinbefore. Electro-hydraulic systems
2 include U. S. Patent Nos. 3,048,165; 3,148,624;
3 3,572,979; 3,636,570; and 3,783,453 and variously involve
4 flexing diaphragms, springs, hydraulic fluid containment
5 tubing and valving in addition to increased bulk and
6 weight.

7 All of the above, non-pneumatic, blood pumps require
8 a compliance chamber when used in a singular or biventricular
9 assist mode or as a total artificial heart. This
10 compliance chamber must accommodate a volume equal to
11 each stroke volume in the assist device and aid in balancing
12 the differences in right and left ventricular
13 stroke volumes.

14 U. S. Patent Nos. 1,061,142; 2,669,668; 3,139,832;
15 3,411,450; 3,420,184; 3,487,784; 3,608,088; and
16 3,647,324 all involve electrically powered centrifugal
17 pumps. These pumps each include a rotating shaft, the
18 shaft passing through a seal in the pumping chamber
19 directly from a motor or a magnetic coupler. As set
20 forth hereinbefore, any seal usually constitutes a very
21 hazardous environment while also being subject to failure
22 by leakage into the shaft bearings.

23 It would, therefore, be a significant advancement in
24 the art to provide a pump characterized by the absence of
25 rotating shafts, seals, bearings, or the like. It would
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1 also be an advancement in the art to provide a novel pump
2 apparatus and method whereby the impellor for the pump is
3 magnetically suspended and rotated in the fluid being
4 pumped. It would also be an advancement in the art to
5 provide a novel method for pumping a fluid with a mag-
6 netically suspended pump impellor. Another advancement
7 in the art is to provide a novel pump apparatus that is
8 characterized by the absence of valves in the stream
9 flow. It would also be an advancement in the art to
10 provide a pump having a novel valve apparatus in
11 combination with the impellor so that when power is
12 interrupted to the impellor, the valving action auto-
13 matically closes under reverse flow when the pump is used
14 in the ventricular assist mode. Such a novel pump
15 apparatus and method is disclosed and claimed herein.

16 Brief Summary and Objects of the Invention

17 The present invention relates to a novel pump appa-
18 ratus and method, the pump including a magnetically
19 suspended and magnetically rotated impellor. The
20 impellor impels fluid through the pump in the absence of
21 shafts, bearings, seals, or the like. The impellor may
22 be configured (a) for axial flow with a hollow,
23 cylindrical-type impellor with impellor vanes on the
24 internal surface thereof or as a streamlined body having
25 impellor vanes located on the external surface of the
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1 body or for (b) centrifugal flow with a generally
2 conical-like shape to the impellor which may be solid,
3 double-ended, hollow, or the like, depending upon design
4 considerations. One impellor design may also include a
5 valve member secured to one end thereof to accommodate
6 seating against a valve seat under reverse flow
7 conditions in the event power is interrupted to the
8 impellor. Sensors adjacent the operating position of the
9 impellor sense the position of the impellor and provide a
10 signal for an electronic circuit for controlling the
11 suspension and/or position of the impellor.

12 It is, therefore, a primary object of this invention
13 to provide improvements in fluid pumps.

14 Another object of this invention is to provide an
15 improved method for pumping fluid with a magnetically
16 suspended and magnetically rotated impellor.

17 Another object of this invention is to provide a
18 fluid pump that is characterized by the absence of moving
19 parts such as seals, shafts, bearings, valves, and the
20 like.

21 Another object of this invention is to provide a
22 control system for magnetically suspending an impellor
23 inside a pump housing.

24 Another object of this invention is to provide a
25 pump apparatus with a novel valve mechanism as part of
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1 the impellor to provide a valve against reverse flow in
2 the event of power interruption to the impellor when the
3 pump apparatus is used as a ventricular assist device.

4 These and other objects and features of the present
5 invention will become more fully apparent from the
6 following description and appended claims taken in
7 conjunction with the accompanying drawing.

8 Brief Description of the Drawing

9 Figure 1 is a perspective view of a first preferred
10 embodiment of the novel pump apparatus of this invention;

11 Figure 2 is a cross-section taken along lines 2-2 of
12 Figure 1;

13 Figure 3 is a cross-sectional view of a second
14 preferred embodiment of the novel pump apparatus of this
15 invention;

16 Figure 4 is a schematic illustration of one embodi-
17 ment of the pump apparatus of this invention shown in the
18 environment of a human torso while being used as a
19 ventricular assist device;

20 Figure 5 is a block diagram of an electronic circuit
21 for controlling and driving the novel pump apparatus of
22 this invention;

23 Figure 6 is a frontal elevation of a third preferred
24 embodiment of the pump apparatus of this invention with
25 portions broken away to reveal internal structure
26 thereof;

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1 Figure 7 is a perspective view of a fourth preferred
2 embodiment of the pump apparatus of this invention;

3 Figure 8 is a cross-section taken along lines 8-8 of
4 Figure 7;

5 Figure 9 is a partial cross-section taken along
6 lines 9-9 of Figure 7;

7 Figure 10 is a cross-section of a fifth preferred
8 embodiment of the novel pump apparatus of this invention;

9 Figure 11 is a cross-sectional view of a sixth
10 preferred embodiment of the novel pump apparatus of this
11 invention;

12 Figure 12 is a cross-sectional view of a seventh
13 preferred embodiment of the novel pump apparatus of this
14 invention; and.

15 Figure 13 is a cross-sectional view of an eighth
16 preferred embodiment of the novel pump apparatus of this
17 invention.

18 Detailed Description of the Preferred Embodiments

19 The invention is best understood by reference to the
20 drawing wherein like parts are designated with like
21 numerals throughout.

22 General Discussion

23 The requirement for improved blood pumps is exempli-
24 fied by the fact that only one total artificial heart has
25 been implanted in a human and, further, that only
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1 moderate success has been attained by clinically applied
2 ventricular assist devices. One of the inventors is
3 aware of these cases and is cognizant of the limitations
4 in the existing clinically applied devices. He is also
5 aware of the devices currently being developed and tested
6 in experimental laboratories. Accordingly, it is an
7 objective of the present invention to satisfy the needs
8 of several human engineering aspects including, for
9 example: (1) physiological requirements, including
10 anatomical space limitations; (2) responsive regulation;
11 (3) safety to other systems including hematologic,
12 cardiovascular, and pulmonary; (4) noninjurious to other
13 organ systems by (a) crowding (pressure necrosis), (b)
14 high, local temperature, and (c) thrombo-embolism; (5)
15 high efficiency to minimize heating and to maximize
16 operational time per battery density; (6) cosmetic and
17 psychological acceptability with (7) high reliability and
18 confidence in durability and maintenance freedom, and (8)
19 low cost of the device.

20 To be suitable as a blood pump, the pump should be
21 able to adequately meet the physiological perfusion needs
22 of a ventricular or biventricular assist device or for
23 total heart replacement. As a total heart replacement
24 device, the pump should be of relatively small size and
25 mass and be completely devoid of flexing diaphragms or
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1 surfaces as well as bearings, friction by rubbing or
2 wearing from mechanical moving parts, etc. Additionally,
3 the pump should be able to effectively dissipate any
4 generated heat into the flowing blood at a sufficiently
5 low level to preclude damage to the blood.

6 The Embodiment of Figures 1 and 2

7 Referring now more particularly to Figures 1 and 2,
8 a first preferred embodiment of the pump apparatus of
9 this invention is shown generally at 10 and includes a
10 pump housing 12 having an inlet 14 and an outlet 16. A
11 coupling 15 is mounted to the end of inlet 14 and serves
12 as an attachment site for attaching pump 10 to either a
13 natural vessel or artificial tubing (not shown).
14 Coupling 17 provides the same features for outlet 16.
15 Clearly, of course, couplings 15 and 17 could be of any
16 suitable configuration to adapt pump 10 for interconnec-
17 tion with any desired tubing, blood vessel, or the like.

18 A drive housing 40 circumscribes pump housing 12 at
19 a position corresponding with the internal location of an
20 impellor 20 (Figure 2), as will be set forth more fully
21 hereinafter, and includes annular support housings 42 and
22 43 on each side. A plurality of sensors 34 and 35 are
23 spaced around the periphery of pump housing 12 adjacent
24 support housings 42 and 43, respectively. The function
25 of each of these components will be discussed more fully
26 hereinafter.

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1 Referring now also to Figure 2, a cross-sectional
2 view of pump apparatus 10 is shown to reveal its internal
3 structure and to more particularly set forth the internal
4 arrangement thereof. Support housing 42 encloses an
5 annularly arrayed set of electromagnets 32 while support
6 housing 43 encloses a corresponding, annularly arrayed
7 set of electromagnets 33. Electromagnets 32 are spaced
8 from electromagnets 33 and each set is selectively con-
9 trolled to provide the appropriate spatial support of
10 impellor 20. In particular, electromagnets 32 and 33
11 maintain the coaxial relationship of impellor 20 inside
12 pump chamber 28, as will be discussed more fully herein-
13 after.

14 Impellor 20 is configured as a hollow, cylindrical
15 member having a plurality of curvilinear vanes 21a-21c
16 mounted on its internal surface. The curvilinear nature
17 of vanes 21a-21c is in the form of parallel, spiral vanes
18 such that axial rotation of impellor 20 in the
19 appropriate direction causes vanes 21a-21c to axially
20 impel fluid through pump apparatus 10 from inlet 14 to
21 outlet 16. Vanes 21a-21c are joined in a valve body 22.
22 Valve body 22 has an external diameter or valve face 24
23 sufficient to allow it to rest against a valve seat 25
24 and thereby obstruct a throat 26 of an inlet valve 23.
25 The function of valve body 22 in cooperation with inlet
26 valve 23 will be discussed more fully hereinafter.

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1 Impellor 20 (in combination with valve body 22)
2 includes a plurality of internally embedded, permanent
3 magnets, magnet sets 11, 36, 38, and 39, annularly
4 arrayed around valve body 22 and impellor 20,
5 respectively. Permanent magnet set 36 cooperates with
6 the corresponding electromagnet set 30 while permanent
7 magnet set 38 cooperates with electromagnet set 32 and
8 permanent magnet set 39 cooperates with electromagnet set
9 33. Operationally, the flow of electrical current to
10 each of electromagnet sets 30, 32, and 33 is selectively
11 regulated to control both the rotation and orientation,
12 respectively, of impellor 20. For example, rotation of
13 impellor 20 is controlled by pump drive circuit 120
14 (Figure 5) directing the input of electrical current to
15 electromagnet set 30. Electromagnet set 30 thus acts as
16 the drive mechanism for rotating impellor 20 in
17 cooperation with permanent magnet set 36.

18 Electrical energy input to each of electromagnet
19 sets 13, 32, and 33 is selectively regulated by the
20 appropriate suspension circuits (suspension circuits 116
21 and 117, Figure 5). These electromagnet sets cooperate
22 with permanent magnet sets, 11, 38, and 39, respectively,
23 to control the coaxial orientation of impellor 20 within
24 pump housing 12. For example, a slight offset in the
25 orientation of impellor 20 (as detected by the plurality
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1 of detectors 34 and 35) will cause sensor circuits 114
2 and 115 (Figure 5) to electrically activate the
3 appropriate sections of electromagnet sets 13, 32 and 33
4 to provide the necessary increase or decrease in
5 repulsive/attractive forces to thereby selectively
6 reorient the suspension of impellor 20 coaxially within
7 pump housing 12.

8 Detector sets 34 and 35 are configured as a
9 plurality of sensor/detector sets which emit and detect a
10 signal as a function of the distances sensed. The sensor
11 system may use either conventional ultrasound, infrared,
12 or other suitable sensor systems. The system operates by
13 detecting changes in signal intensity and/or frequency as
14 a function of changes in the relative position of
15 impellor 20. These signal changes are received by the
16 appropriate sensor circuit (left sensor circuit 114 or
17 right sensor circuit 115, Figure 5), and interpreted by
18 signal controller 118 (Figure 5). Electrical energy is
19 thereby suitably regulated to either or both of electro-
20 magnet sets 32 and/or 33 to suitably adjust and/or
21 maintain the predetermined position of impellor 20 inside
22 pumping chamber 28. Importantly, impellor 20 is
23 suspended within the confines of pumping chamber 28 with
24 a narrow annular space 19 surrounding the same. Annular
25 space 19 provides clearance for impellor 20 and also,
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1 advantageously, accommodates a limited backflush of fluid
2 therethrough to preclude stagnation, heat buildup, or the
3 like between impellor 20 and housing 12.

4 With particular reference also to Figure 4, pump 10,
5 Figures 1 and 2, is shown schematically at 90 as a ventri-
6 cular assist pump 94 in the environment of a human torso
7 92. Pump 94 is interconnected at apex 104 of a heart 100
8 by an inlet conduit 103. An outlet conduit 101 inter-
9 connects pump 94 to the aortic arch 102. Accordingly,
10 the natural heart 100 is not replaced but is merely
11 assisted with pump 94, either as a long-term implant or
12 as a temporary assist device. In the embodiment shown,
13 pump 94 is implanted as a semipermanent implantation and
14 includes a power supply 96 supplying power to pump 94
15 through leads 95. Leads 97 connect power supply 96 to an
16 induction coil 98 so that power supply 96 can be
17 recharged by bringing a corresponding induction coil (not
18 shown) adjacent induction coil 98 according to
19 conventional techniques.

20 Pump 10 (Figures 1 and 2) and pump 94 (Figure 4) are
21 both adapted as ventricular assist devices. Pump 10 is
22 particularly adapted since it includes the valve
23 mechanism of valve seat 25 adapted to receive valve face
24 24 of valve body 22. As a ventricular assist device,
25 pump 10 is used only to supplement the pumping action of
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1 heart 100 (Figure 4) so that an interruption of
2 electrical power to electromagnets 13, 30, 32, and 33
3 will not be catastrophic. Instead, the existing
4 backpressure in pump 10 causes a momentary reverse flow
5 of fluid from outlet 16 toward inlet 14 with a
6 corresponding reverse movement of impellor 20 toward
7 inlet 14. This reverse movement brings valve body 22
8 and, more particularly, valve face 24 into sealing
9 contact with valve seat 25. In this manner, reverse flow
10 is promptly stopped upon failure of pump 10.

11 Referring again to Figure 2, outlet 16 is shown
12 having an angular offset from the axial orientation of
13 pump housing 12 for the purpose of (1) more readily
14 adapting pump apparatus 10 to placement within the ana-
15 tomical space adjacent a heart and (2) decreasing the
16 tendency for the pumped blood to swirl as a result of
17 being pumped by rotation of impellor 20. Swirling motion
18 is also decreased by including a stator vane 18 inside
19 outlet 16.

20 The Embodiment of Figure 3

21 Referring now more particularly to Figure 3, a
22 second preferred embodiment of the novel pump apparatus
23 of this invention is shown generally at 50 and includes a
24 pump housing 52 having an inlet 54 and an outlet 56. An
25 attachment site 55 is provided on inlet 54 and an attach-
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1 ment site 57 is provided on outlet 56 for the purpose of
2 readily adapting pump apparatus 50 to be interconnected
3 into the appropriate size natural and/or artificial
4 tubing (not shown, but see conduits 103 and 101,
5 respectively, Figure 4). Although pump apparatus 50 is
6 shown substantially enlarged over that of pump apparatus
7 10 (Figures 1 and 2), it should be clearly understood
8 that the size may be selectively predetermined and is
9 shown enlarged herein only for ease of illustration
10 convenience.

11 Pump 50 includes a drive and support housing 58
12 enclosing an inlet electromagnet support set 62, an
13 outlet support electromagnet set 63 and a drive
14 electromagnet set 60 therein. An impellor 70 within pump
15 housing 52 is configured as a hollow cylindrical member
16 having a plurality of impellor vanes 71a and 71b mounted
17 on the interior surface thereof. A plurality of
18 permanent magnet sets 66, 68, and 69 are embedded in the
19 external periphery of impellor 70. Permanent magnet set
20 68 corresponds to inlet support electromagnet set 62 and
21 permanent magnet set 69 corresponds to outlet
22 electromagnet support set 63 while permanent magnet set
23 66 corresponds to drive electromagnet set 60.
24 Accordingly, the overall function of impellor 70 is
25 substantially similar to the operation of impellor 20
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1 (Figure 2), as set forth hereinbefore. Axial rotation of
2 impellor 70 causes impellor vanes 71a and 71b to push
3 against the fluid (not shown) impelling the same from
4 inlet 54 toward outlet 56.
5

6 It should be noted that the angular orientation
7 between inlet 54 and outlet 56 relative to impellor 70 is
8 such that it more readily adapts pump apparatus 50 to
9 placement in the anatomical cavity adjacent or in place
10 of the natural heart while substantially reducing the
11 swirling action imparted to the fluid by impellor 70, as
12 set forth hereinbefore with respect to pump apparatus 10
13 (Figures 1 and 2). Pump 50 may also include guide vanes
14 18 (Figure 2) to reduce swirl in the pumped fluid. From
15 the foregoing, it is clear that pump apparatus 50 is
16 substantially similar in operation to pump apparatus 10
17 with the exception that pump apparatus 50 does not
18 include a valve member 22 affixed thereto.

19 Pump apparatus 50 includes a plurality of inlet
20 sensors 64 and outlet sensors 65 to selectively determine
21 the orientation of impellor 70 relative to pump housing
22 52. The position of impellor 70, as detected by sensors
23 64 and 65, is selectively controlled by a signal con-
24 troller 118 (Figure 5) which in turn selectively controls
25 each of electromagnet sets 62 and 63. Importantly, the
26 spatial orientation of impellor 70 is maintained
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1 coaxially within housing 52 with a surrounding space 72
2 which permits backflush and also precludes rubbing by
3 impellor 70.

4 The Embodiment of Figure 6

5 Referring now more particularly to Figure 6, a third
6 preferred embodiment of the pump apparatus of this
7 invention is shown generally at 150 and includes a pump
8 housing 158 having an inlet 154 and an outlet 156 with an
9 impellor 170 suspended therein. Pump housing 158
10 encloses a plurality of electromagnet sets 160, 162 and
11 163. Electromagnet set 160 forms an annular array and
12 serves as a drive electromagnet system for axially
13 rotating impellor 170. Electromagnet sets 162 and 163
14 form annular arrays of electromagnets at each end of
15 impellor 170 and are selectively controlled to provide
16 the necessary suspension or orientation of impellor 170
17 inside pump housing 158. The position of impellor 170 is
18 determined by detector sets 164 and 165 annularly arrayed
19 around pump housing 158. A controller such as signal
20 controller 118 (Figure 5) electronically analyzes signals
21 received by the plurality of detectors 164 and 165 and
22 provides the necessary control signals to the left and
23 right suspension circuits (left suspension circuit 116
24 and right suspension circuit 117, Figure 5) for driving
25 electromagnet sets 162 and 163.

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1 Impellor 170 is configured as a cylindrical,
2 aerodynamic body and includes a plurality of impellor
3 vanes 171a-171c mounted externally thereon. Impellor 170
4 also includes a plurality of annularly arrayed permanent
5 magnet sets 166, 168, and 169 corresponding generally to
6 magnet sets within the various impellers, impellor 70,
7 (Figure 3) and impellor 20 (Figure 2). Electromagnet
8 sets 162 and 163 cooperate with permanent magnet sets 168
9 and 169, respectively. Impellor 70 is suspended inside
10 the pump housing of pump 150 with a space 172 maintained
11 therebetween to minimize rubbing by impellor 170. Drive
12 electromagnet set 160 cooperates with permanent magnet
13 set 166 for the purpose of causing rotation of impellor
14 170.

15 The primary difference between the pump apparatus
16 150 of this third preferred embodiment and that of either
17 of the second or third preferred embodiments of Figures
18 1-3 is that the impellor vanes, impellor vanes 171a-171c,
19 are mounted on the external surface of impellor 170,
20 whereas the various impellor vanes of the other two
21 embodiments are located on the internal surface of a
22 hollow, cylindrical impellor member. Impellor 170 could
23 also include a valve member similar to valve member 22
24 (Figure 2) formed on the inlet end adjacent inlet 154 to
25 cooperate with a valve seat (not shown) configured
26 substantially similar to valve seat 25 (Figure 2).

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1 Referring now more particularly to Figure 5, the
2 electronic circuitry of the control, sensor, and
3 suspension circuits are conventional systems and are,
4 therefore, shown schematically. These systems include a
5 power supply 112 electrically connected to the pump drive
6 circuit 120 controlled by control circuit 119. A left
7 sensor circuit 114 and a right sensor circuit 115 provide
8 the necessary signal input to a signal controller 118
9 which, in turn, provides the necessary control signals to
10 left suspension circuit 116 and right suspension circuit
11 117, respectively, to thereby selectively control the
12 orientation and suspension of the respective impellor
13 inside of the respective pump housing. Additionally, the
14 appropriate feedback circuitry is provided to accommodate
15 sensing the electromotive force being applied to the pump
16 drive circuit as a function of pressure to thereby
17 readily adapt the apparatus and method of this invention
18 for being able to regulate pressure as determined by the
19 pump drive circuit and the amount of energy input to the
20 respective drive electromagnet set.

21 The Embodiment of Figures 7-9

22 Referring now more particularly to Figures 7-9, a
23 fourth preferred embodiment of the novel pump apparatus
24 of this invention is shown generally at 200 and includes
25 a pump housing 202 with an impellor 220 suspended and
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1 rotated magnetically therein as will be discussed more
2 fully hereinafter. Inlets 204 and 206 are provided on
3 opposing faces of pump housing 202 for receiving fluid
4 therein. Each of inlets 204 and 206 have rims 205 and
5 207, respectively, formed thereon for ease in attaching
6 tubing (not shown) to pump 200. The dual inlets 204 and
7 206 are believed to provide a more uniform flow pattern
8 for pump 200 thereby substantially minimizing the balance
9 requirements for impellor 220 with a corresponding lower
10 consumption of energy for the magnetic bearing system.
11 Impellor 220 is configured with a conical apex 210 and
12 212 on each end thereof to present a smooth flow profile
13 to the incoming fluid through the respective inlets 204
14 and 206. Fluid (not shown) drawn into pump 200 through
15 inlets 204 and 206 is centrifugally impelled outwardly
16 through a discharge conduit 208 formed as a tangential
17 outlet. A rim 209 on conduit 208 serves as an attachment
18 site for tubing (not shown) to pump 200. Incoming fluid
19 through inlet 204 is received in an inlet chamber 214
20 while incoming fluid through inlet 206 is received in an
21 inlet chamber 216. Rotation of impellor 220 causes
22 impellor vanes 250 and 251 to impart an outward
23 centrifugal momentum to the fluid forcing it into two
24 peripheral, scroll chambers 228 and 230 and join as
25 discharge conduit 208. A septum 224 divides scroll
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1 chamber 230 into an outer scroll chamber 226 and an inner
2 scroll chamber 228 (Figure 9) for reduction of turbulence
3 during operation of pump 200. Septum 224 not only
4 reduces turbulence, but also lowers any tendency toward
5 cavitation, stagnation, and the like, that would
6 otherwise be experienced by fluid in scroll chamber 230.
7 The structure of septum 224 provides two tangential
8 outlets 180° apart to compensate for the radial forces on
9 impellor 220 with a corresponding lower consumption of
10 energy for the magnetic bearing system.
11

12 A permanent magnet 264 is configured as a
13 cylindrical magnet extending between conical apices 210
14 and 212. Permanent magnet 264 cooperates between ring
15 magnets 236 and 238 to which are coupled coil windings
16 237 and 239, respectively, to assist in maintaining the
17 directional stability of pump impellor 220. A plurality
18 of C-shaped electromagnets 232-235 (Figure 9) cooperate
19 with corresponding permanent magnets 260-263 in the
20 circumferential periphery of impellor 220 to cause the
21 same to rotate in a generally clockwise direction (when
22 viewed in Figure 9). Windings 232a and 232b with respect
23 to electromagnet 232 and windings 234a and 234b with
24 respect to electromagnet 234 control the
25 repulsive/attractive forces of the respective magnet
26 systems. Pump 200 also includes a sensor system (see
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1 Clockwise rotation of impellor 220 causes vane sets 250
2 and 251 thereon to impart the necessary propulsion to the
3 fluid entering inlets 204 and 206, respectively, and
4 impel the same through scroll chamber 230.

5 The Embodiment of Figure 10

6 Referring now more particularly to Figure 10, an
7 axial, cross-sectional view of a fifth preferred
8 embodiment of the novel pump apparatus of this invention
9 is shown generally at 300 and includes a pump body 302
10 having an impellor 320 magnetically suspended and rotated
11 therein as will be discussed more fully hereinafter.
12 Dual inlets to pump 300 are provided by inlets 304 and
13 306 with fluid being drawn thereinto into inlet chambers
14 314 and 316, respectively.

15 Impellor 320 impels the fluid into a surrounding
16 scroll chamber 330 during the pumping operation.
17 Impellor 320 is configured as a generally hollow
18 impellor having inlet ports 374 and 376 splitting into
19 discharge channels 374a and 374b and discharge channels
20 376a and 376b, respectively. A flow profile body 380 is
21 supported interiorly inside impellor 320 by supports
22 (not shown). Flow profile body 380 is configured with
23 a generally double conical configuration to provide a
24 smooth flow profile through the hollow interior of
25 impellor 320. The external surface of impellor 320

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1 includes a plurality of vanes 350a and 350b on the side
2 of inlet 304 and vanes 351a and 351b on the side of inlet
3 306. The combination of vanes 350a, 350b, 351a, and
4 351b, in combination with the hollow center to impellor
5 320 provides a substantially improved flow pattern for
6 impellor 320.

7 Permanent magnets 370 and 372 embedded in each end
8 of impellor 320 respectively cooperate with electromagnet
9 sets 336 on the left and electromagnet set 338 on the
10 right, each of the respective electromagnet sets being
11 selectively controlled by windings 337 and 339,
12 respectively. This combination of permanent magnets and
13 corresponding electromagnet sets provides the necessary
14 suspension system for impellor 320 in pump body 302.
15 Suspension of impellor 320 is achieved by a sensor and
16 suspension system (not shown, but see Figures 1-3, 5, and
17 6) so that impellor 320 is magnetically suspended in
18 housing 302 to provide the desired spatial separation or
19 gap 322 between impellor 320 and housing 302.

20 A plurality of permanent magnets 360 and 362 are
21 embedded in the circumferential periphery of impellor 320
22 and cooperate with horseshoe-shaped electromagnets 332
23 and 334. Electromagnets 332 and 334 are selectively
24 driven by windings 332a and 332b with respect to
25 electromagnet 332 and windings 334a and 334b which drive
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1 electromagnet 334. Electromagnets 332 and 334 cooperate
2 with permanent magnets 360 and 362 to drive impellor 320
3 in the appropriate direction for the pumping operation..

4 The Embodiment of Figure 11

5 Referring now more particularly to Figure 11, a
6 sixth preferred embodiment of the novel pump apparatus of
7 this invention is shown generally at 400 and includes a
8 pump housing 402 with an impellor 420 magnetically
9 suspended and rotated therein. Inlets 404 and 406 on
10 each end of pump housing 402 admit fluid into inlet
11 chambers 414 and 416, respectively. Rims 405 and 407 on
12 inlets 404 and 406, respectively, provide attachment
13 sites for natural or artificial tubing (not shown) to
14 pump 400. Fluid entering inlet chambers 414 and 416 is
15 centrifugally impelled by impellor 420 into a surrounding
16 scroll chamber 430.

17 Impellor 420 is configured as a generally hollow
18 impellor having an inlet 474 and a plurality of guide
19 vanes 474a therein on one side and a corresponding hollow
20 inlet 476 with a plurality of guide vanes 476a therein on
21 the other side. The central position of impellor 420 is
22 occupied by a flow profile body 480 configured as a
23 double apex cone member to present a smooth flow profile
24 for fluid passing through the hollow center of impellor
25 420. Guide vanes 474a and 476a are supported interiorly
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1 in impellor 420 by support members indicated
2 schematically herein as support members 481 and 483.
3 Rotation of impellor 420 causes fluid entering inlet
4 chambers 414 and 416 to be drawn through the passageways
5 between guide vanes 474a and 476a, respectively, and
6 through the surrounding gap 422 between impellor 420 and
7 pump housing 402 centrifugally discharging the same into
8 the surrounding scroll chamber 430.

9 A permanent magnet 470 embedded in one end of
10 impellor 420 cooperates with surrounding electromagnet
11 set 436 controlled by windings 437 to suitably suspend
12 the left side of impellor 420 in the hollow of pump
13 housing 402. Correspondingly, a permanent magnet 472
14 cooperates with a surrounding electromagnet set 438
15 controlled by windings 439 to suspend the right side of
16 impellor 420 in pump housing 402. A suitable
17 sensor/suspension system (see Figures 1-3, 5 and 6) is
18 provided to maintain the spatial orientation of impellor
19 420 inside pump housing 402.

20 Rotation of impellor 420 is provided by a plurality
21 of permanent magnets 460 and 462 embedded in the
22 circumferential periphery of impellor 420. Permanent
23 magnets 460 and 462 cooperate with C-shaped
24 electromagnets 432 and 434 (as controlled by windings
25 432a and 432b with respect to electromagnet 432 and
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1 windings 434a and 434b with respect to electromagnet 434)
2 to impart the necessary rotational movement of impellor
3 420. Electrical energy to drive the respective windings
4 of electromagnets 432 and 434 is supplied by a pump drive
5 circuit 120 (Figure 5). It will be noted that impellor
6 420 does not incorporate vanes (for example, see vane
7 sets 350 and 351, Figure 10). Instead, impellor 420
8 relies on the natural frictional engagement between the
9 extended surface areas interiorly and exteriorly of
10 impellor 420 in cooperation with the relatively narrow
11 spatial separation of these surfaces to cause impellor
12 420 to centrifugally impel the fluid into scroll chamber
13 430.

14 The Embodiment of Figure 12

15 Referring now more particularly to Figure 12, a
16 seventh preferred embodiment of the novel pump apparatus
17 of this invention is shown generally at 500 and includes
18 a pump housing 502 with an impellor 520 magnetically
19 suspended and rotated therein between an inlet 504 and a
20 surrounding scroll chamber 530. A rim 505 on inlet 504
21 serves as an attachment site for the attachment of a
22 tubing (not shown) to inlet 504. It will be particularly
23 noted with respect to pump 500 that only a single inlet
24 504 having an inlet chamber 506 is provided. Rotation of
25 impellor 520 causes incoming fluid to be discharged into
26 scroll chamber 530.

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1 Impellor 520 includes a hollow center 574 having
2 vanes 550c and 550d on the inner surface thereof while
3 vanes 550a and 550b are mounted exteriorily of impellor
4 520. Incoming fluid into an inlet chamber 506 either
5 passes exteriorily of impellor 520, as impelled by vanes
6 550a and 550b, or otherwise interiorily of impellor 520
7 as impelled by impellor vanes 550c and 550d with the
8 impelled fluid being discharged into the surrounding
9 scroll chamber 530. Impellor 520 is suspended in pump
10 body 502 by cooperation between permanent magnets 570 and
11 572, embedded in impellor 520 and corresponding
12 electromagnet set 536 controlled by windings 537 in
13 addition to electromagnet 538 and controlled by winding
14 539 to magnetically suspend impellor 520 in the pump body
15 502. A sensor/suspension system (for example, see
16 Figures 1-3, 5, and 6) is provided to selectively control
17 windings 537 and 539 to thereby maintain the desired
18 orientation of impellor 520 inside pump housing 502 and,
19 more particularly, the spatial separation or gap 522
20 between impellor 520 and pump housing 502.

21 Permanent magnets 560 and 562 are mounted on the
22 periphery of impellor 520 and cooperate with C-shaped
23 electromagnet 532 (controlled by windings 532a and 532b)
24 and electromagnet 534 (controlled by windings 534a and
25 534b) to impart the necessary rotary motion to impellor
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1 520. A pump drive circuit (pump drive circuit 120,
2 Figure 5) selectively provides the necessary electrical
3 energy to windings 532a, 532b, 534a and 534b to cause
4 impellor 520 to be rotated inside pump housing 502.

5 The Embodiment of Figure 13

6 Referring now more particularly to Figure 13, an
7 eighth preferred embodiment of the novel pump apparatus
8 of this invention is shown generally at 600 and includes
9 a pump housing 602 having an impellor 620 magnetically
10 suspended and rotated therein. A single inlet 604 admits
11 a fluid into an inlet chamber 606. A rim 605 on inlet 604
12 serves as an attachment site for tubing (not shown)
13 mounted to pump 600.

14 Impellor 620 is configured substantially similar
15 to impellor 520 (Figure 12) with the exception that
16 impellor 620 includes a plurality of guide vanes 682
17 mounted interiorly on spaced mounting brackets indicated
18 generally at 681. The interior of impellor 620 provides
19 a flow channel 674 divided into a plurality of subflow
20 channels 674a by guide vanes 682 thereby substantially
21 eliminating undue turbulence, backflow, and the like that
22 might otherwise be experienced upon rotation of impellor
23 620.

24 Impellor 620 is suspended in pump housing 602 by a
25 plurality of permanent magnets 672 and 674 embedded
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1 therein and which cooperate with a corresponding
2 electromagnetic support system. The electromagnetic
3 support system is provided by electromagnet set 636
4 (controlled by winding 637) and electromagnet 638
5 (controlled by winding 639) which cooperate with
6 permanent magnets 672 and 674, respectively, to suspend
7 impellor 620 inside pump housing 602. A
8 sensor/suspension circuit (for example, see Figures 1-3,
9 5 and 6) is provided to selectively suspend impellor 620
10 inside pump housing 602 with the appropriate spatial
11 separation or gap 622 therebetween.

12 Impellor 620 also includes permanent magnets 660 and
13 662 embedded in the external periphery. Permanent
14 magnets 660 and 662 cooperate sequentially with C-shaped
15 electromagnet 632 (controlled by windings 632a and 632b)
16 in combination with C-shaped electromagnet 634
17 (controlled by windings 634a and 634b), respectively. A
18 pump drive circuit (pump drive circuit 120, Figure 5)
19 selectively provides the necessary electrical energy to
20 windings 632a, 632b, 634a and 634b to cause impellor 620
21 to be rotated inside pump housing 602.

22 In each of the embodiments set forth herein in
23 Figures 7-13, it will be noted that the pump apparatus is
24 configured as a centrifugal pump apparatus wherein a
25 coaxial inflow of fluid is impelled outwardly by a
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1 rotating impellor into the surrounding scroll chamber and
2 discharged tangentially through the corresponding
3 outlet, such as outlet 208 (Figures 7 and 9). The
4 pumping apparatus of Figures 7-11 discloses double inlets
5 at each end of the impellor, with the impellor therein
6 being configurated as a generally double-ended conical
7 member. Dual inlets advantageously balance the axial
8 forces against the respective impellor as the fluid is
9 impelled outwardly by the impellor. This balancing of
10 forces substantially reduces the energy consumption of
11 the magnetic suspension system. The pump apparatus of
12 Figures 10 and 11 disclose variations in hollow impellor
13 apparatus for improved flow profiles therethrough.

14 The pump apparatus of Figures 12 and 13 relates to a
15 single inlet pump with variations in the flow profile
16 through the center of the impellor suspended therein.
17 The impellors of Figures 12 and 13 are configurated with
18 a flow-through channel to preclude stagnation of fluids
19 behind the impellor as would otherwise occur if there
20 were no flow channel.

21 Importantly, each impellor can be fabricated from
22 suitable materials so that the specific gravity of the
23 impellor can be made to match the specific gravity of the
24 particular fluid being pumped. This matching of specific
25 gravities is particularly desirable in that it reduces
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1 the energy required to magnetically suspend the impellor
2 during operation and also the energy required to
3 magnetically overcome external acceleration forces upon
4 sudden movements of the entire pump. The selection of
5 materials of construction is also directed toward the
6 unencumbered selection of blood-compatible materials,
7 many of which are well-known in the art.

8 In each embodiment herein, the design of each
9 impellor is specifically coordinated to minimize
10 hemolysis of the blood due to critical shear stresses
11 imposed on the blood, particularly in the gap between the
12 moving impellor and the stationary housing. Clearly, the
13 size of the required gap is a function of the radial
14 velocity of the impellor as determined by the diameter of
15 the impellor and the rate of rotation. For most blood
16 pump operations, this gap is about 1 mm.

17 The driving sytem for rotating the respective
18 impellors can be of any suitable type such as an
19 asynchronous motor, especially one using induced eddy
20 currents. Also, it is to be clearly understood that the
21 driving systems and the magnetic suspension systems can
22 be configurated to use the same components
23 simultaneously. Rotational speed can be controlled by a
24 closed loop system using either the signal of the
25 position sensors of the magnetic suspension system or the
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1 induced electromotive forces. Sensors similar to sensor
2 sets 34 and 35 (Figures 1 and 2), sensor sets 64 and 65
3 (Figure 3), or sensor sets 164 or 165 (Figure 6) may be
4 included selectively in any of pump 200 (Figures 7-9),
5 pump 300 (Figure 110), pump 400 (Figure 11), pump 500
6 (Figure 12), and pump 600 (Figure 13).

7 The invention may be embodied in other specific
8 forms without departing from its spirit or essential
9 characteristics. The described embodiments are to be
10 considered in all respects only as illustrative and not
11 restrictive and the scope of the invention is, therefore,
12 indicated by the appended claims rather than by the
13 foregoing description. All changes which come within the
14 meaning and range of equivalency of the claims are to be
15 embraced within their scope.

16 What is claimed and desired to be secured by United
17 States Letters Patent is:

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1. A fluid pump comprising:

a pump housing;

an impellor means in the housing;

magnetic suspension means for magnetically
suspending the impellor means in the housing; and

magnetic rotation means for magnetically
rotating the impellor means.

2. The fluid pump defined in Claim 1 wherein the
pump housing comprises an inlet means and an outlet.

3. The fluid pump defined in Claim 2 wherein the
inlet means and the outlet are coaxial.

4. The fluid pump defined in Claim 2 wherein the
inlet means is angularly offset from the outlet.

5. The fluid pump defined in Claim 2 wherein the
outlet is tangentially offset from the inlet means.

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1 6. The fluid pump defined in Claim 5 wherein the
2 inlet means comprises coaxial inlets on each side of the
3 pump housing.
4

5 7. The fluid pump defined in Claim 5 wherein the
6 inlet means comprises a single inlet.
7

8 8. The fluid pump defined in Claim 1 wherein the
9 impellor means comprises an axially rotatable member.
10

11 9. The fluid pump defined in Claim 8 wherein the
12 rotatable member comprises a streamlined shape having
13 impellor vanes mounted externally thereon.
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1 10. The fluid pump defined in Claim 9 wherein the
2 pump housing comprises a valve seat in an inlet to the
3 pump housing and the impellor means comprises a valve
4 body on an end of the impellor means toward said valve
5 seat, the valve body being operable to occlude said valve
6 seat.

7
8 11. The fluid pump defined in Claim 1 wherein the
9 impellor means comprises a hollow, cylindrical member
10 having a plurality of impellor vanes on the internal
11 surface of the member.

12
13 12. The fluid pump defined in Claim 11 wherein the
14 pump housing comprises an inlet and a valve seat in the
15 inlet and the impellor means comprises a valve body on an
16 end of the impellor means facing the valve seat, the
17 valve body being operable to occlude the inlet when
18 contacted against the valve seat.

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1 13. The fluid pump defined in Claim 1 wherein the
2 impellor means comprises a centrifugal impellor having a
3 generally frustoconical profile.

4
5 14. The fluid pump defined in Claim 13 wherein the
6 centrifugal impellor comprises a plurality of externally
7 mounted impellor vanes.

8
9 15. The fluid pump defined in Claim 13 wherein the
10 centrifugal impellor comprises a hollow center.

11
12 16. The fluid pump defined in Claim 15 wherein the
13 centrifugal impellor comprises a plurality of impellor
14 vanes inside the hollow center.

15
16 17. The fluid pump defined in Claim 1 wherein the
17 magnetic suspension means comprises sensing means for
18 sensing the position of the impellor means inside the
19 pump housing.

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1 18. The fluid pump defined in Claim 1 wherein the
2 magnetic suspension means comprises a first magnetic
3 suspension ring circumscribing the pump housing at a
4 first position and a second magnetic suspension ring
5 circumscribing the pump housing at a second position
6 spaced from the first position.

7
8 19. The fluid pump defined in Claim 18 wherein the
9 magnetic suspension means comprises a sensing means
10 coupled to the suspension means, the sensing means opera-
11 ble to detect the relative position of the impellor means
12 in the pump housing and to generate a signal operable to
13 control the magnetic suspension means as a function of
14 the signal.

15
16 20. The fluid pump defined in Claim 19 wherein the
17 sensing means comprises a sensing means selected from the
18 group consisting of ultrasound sensing means and infrared
19 sensing means, the sensing means being operable to
20 generate a signal and detect said signal as a function of
21 the position of said impellor means.

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1 21. The fluid pump defined in Claim 1 wherein the
2 magnetic rotation means comprises a plurality of magnet
3 means arrayed in a ring about the pump housing and opera-
4 ble to rotate the pump impellor means.

5
6 22. The fluid pump defined in Claim 1 wherein
7 impellor means comprises an impellor fabricated from a
8 material having a specific gravity substantially
9 corresponding to the specific gravity of the fluid.

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1 23. A pump for fluids, the pump comprising:

2 a pump housing having an inlet and an outlet
3 and a pumping section between the inlet and the
4 outlet;

5 an impellor means in the pump housing and
6 operable to impel the fluids through the pump
7 housing from the inlet to the outlet;

8 magnetic suspension means for suspending the
9 impellor means in the pump housing;

10 magnetic rotation means for rotating the
11 impellor means to impel fluids through the pump
12 housing from the inlet to the outlet; and

13 sensing means for sensing the position of the
14 impellor means.

15
16 24. The pump defined in Claim 23 wherein the im-
17 pellor means comprises a hollow, cylindrical member
18 having a plurality of impellor vanes mounted on the
19 inside surface of the hollow, cylindrical member.
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1 25. The pump defined in Claim 23 wherein the
2 impellor means comprises an elongated, aerodynamic body
3 having a diameter incrementally less than the diameter of
4 the pumping section of the pump housing thereby leaving
5 an annular space between the body and the pump housing,
6 the impellor means further comprising a plurality of
7 impellor vanes mounted externally on the body in the
8 annular space between the body and the pump housing.

9
10 26. The pump defined in Claim 23 wherein the
11 impellor means comprises an impellor body having a
12 specific gravity approximating the specific gravity of
13 the fluid being pumped.

14
15 27. The pump defined in Claim 23 wherein the
16 impellor means comprises an impellor body having a fluid
17 passage through at least a portion of the impellor body.

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1 28. The pump defined in Claim 23 wherein the
2 magnetic suspension means comprises a first magnetic
3 means in the impellor means, a second magnetic means in
4 the pump housing and control means for controlling at
5 least one of the first magnetic means and the second
6 magnetic means to suspend the impellor means inside the
7 pump housing as a function of the sensing means.
8

9 29. A method for pumping a fluid comprising:
10

11 obtaining a pump housing;

12 inserting an impellor inside the pump housing;

13 interconnecting the pump housing in a fluid
14 conduit;

15 sensing the position of the impellor inside the
16 pump housing;

17 magnetically suspending the impellor inside
18 the pump housing as a function of the sensing step;
19 and

20 magnetically rotating the impellor thereby
21 impelling fluid through the fluid conduit.
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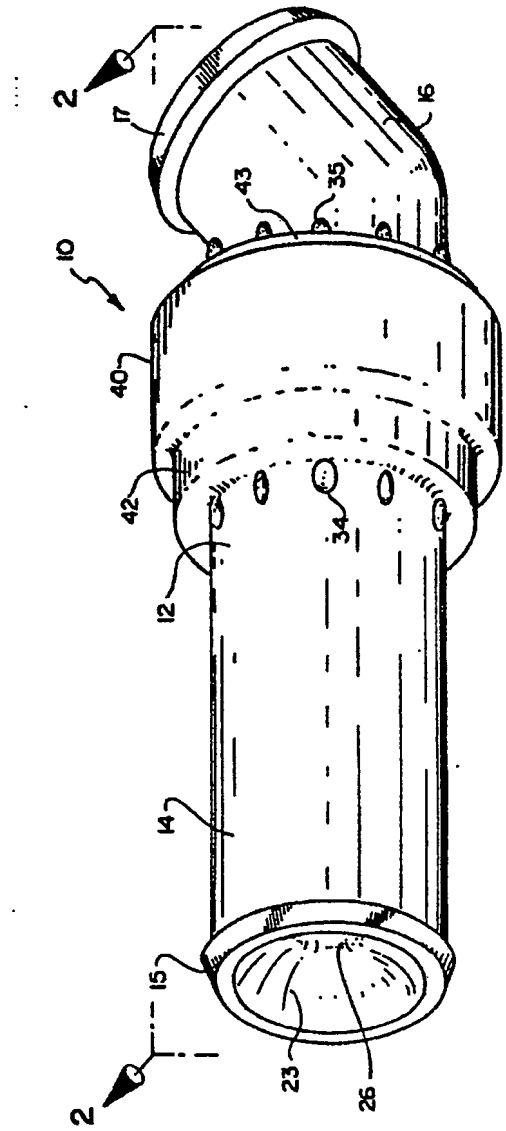


Fig. 1

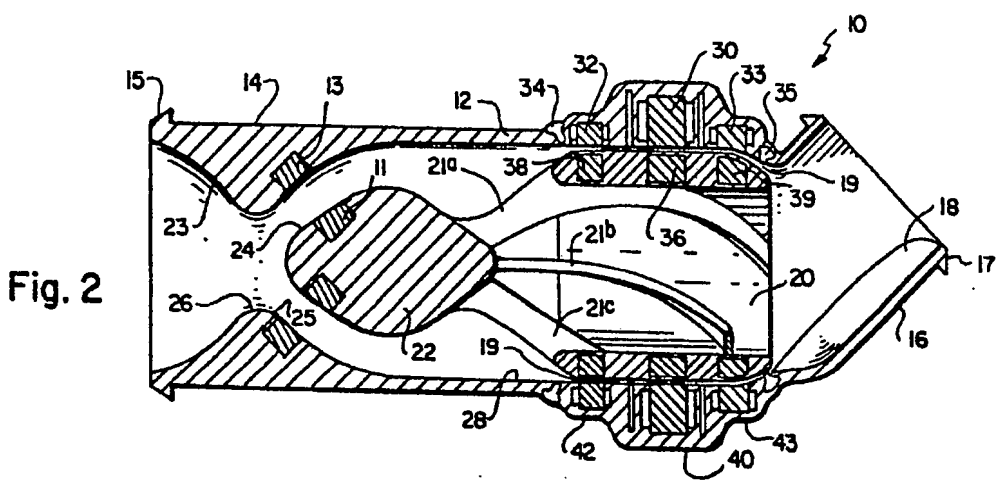


Fig. 2

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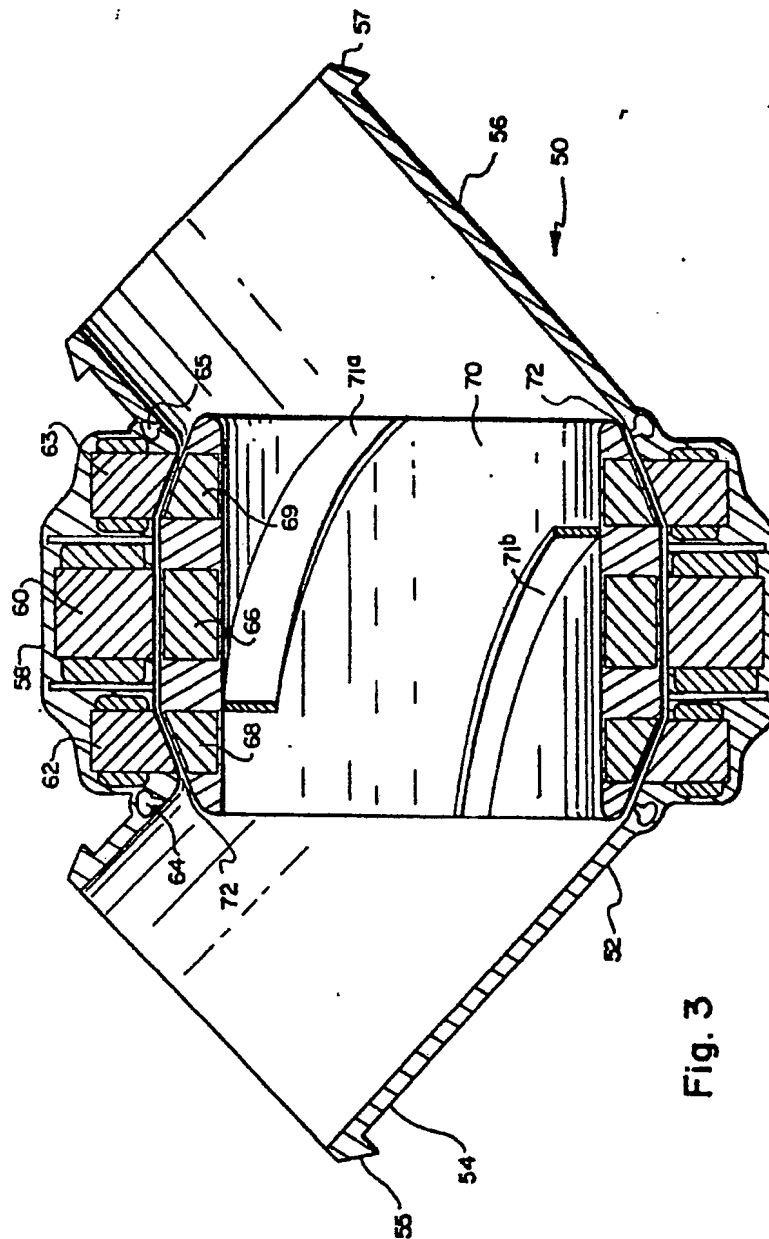


Fig. 3

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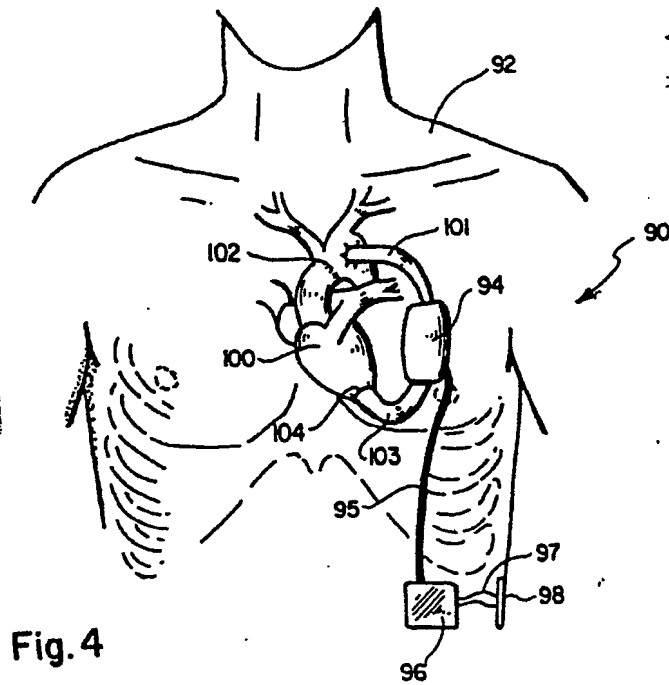


Fig. 4

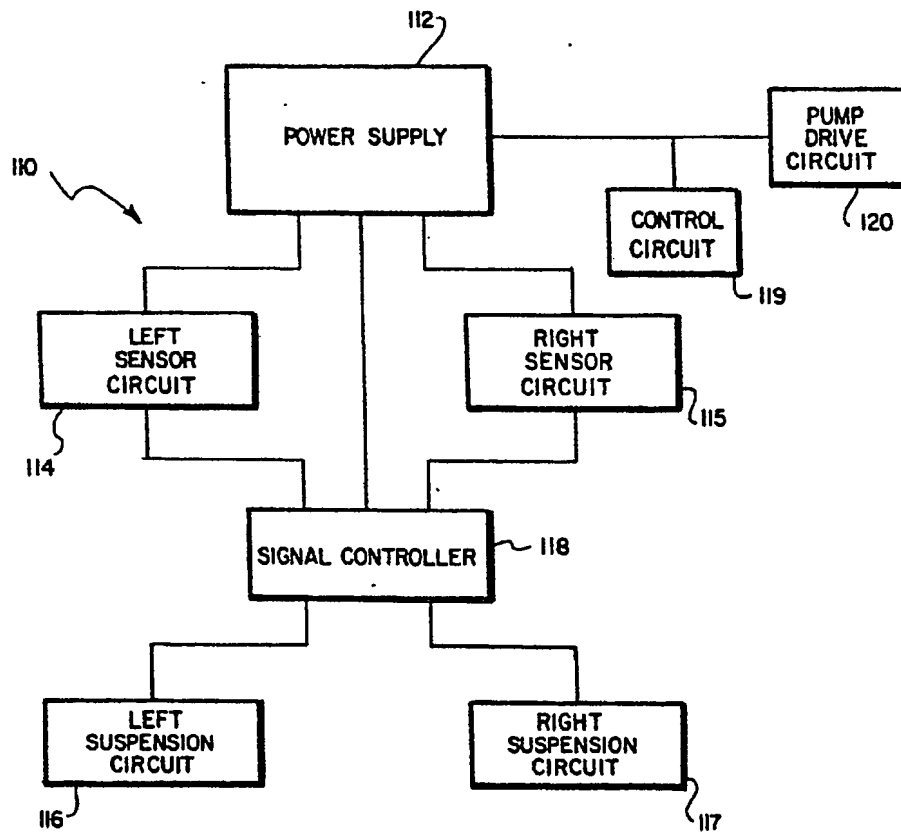


Fig. 5

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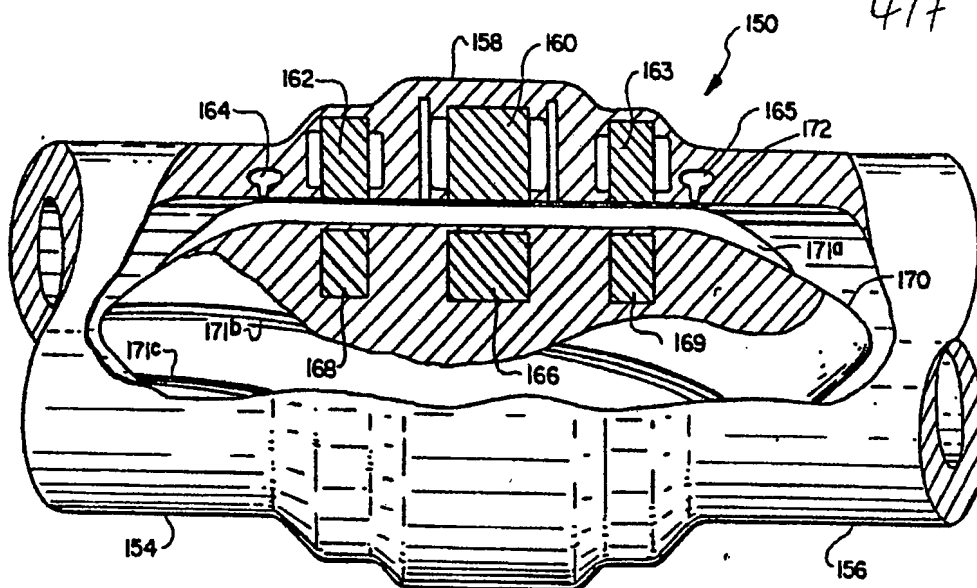


Fig. 6

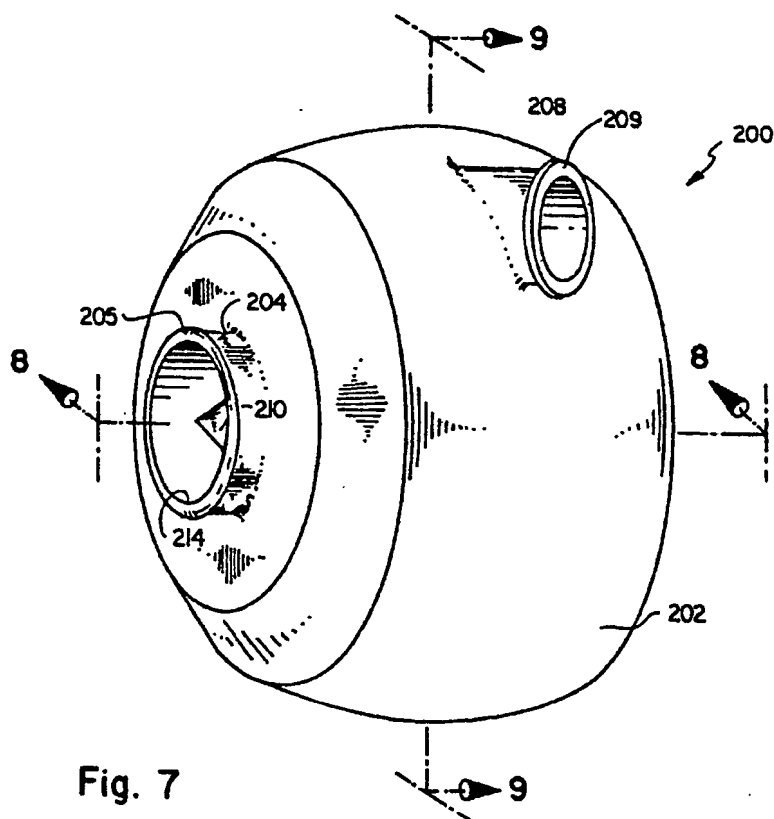


Fig. 7

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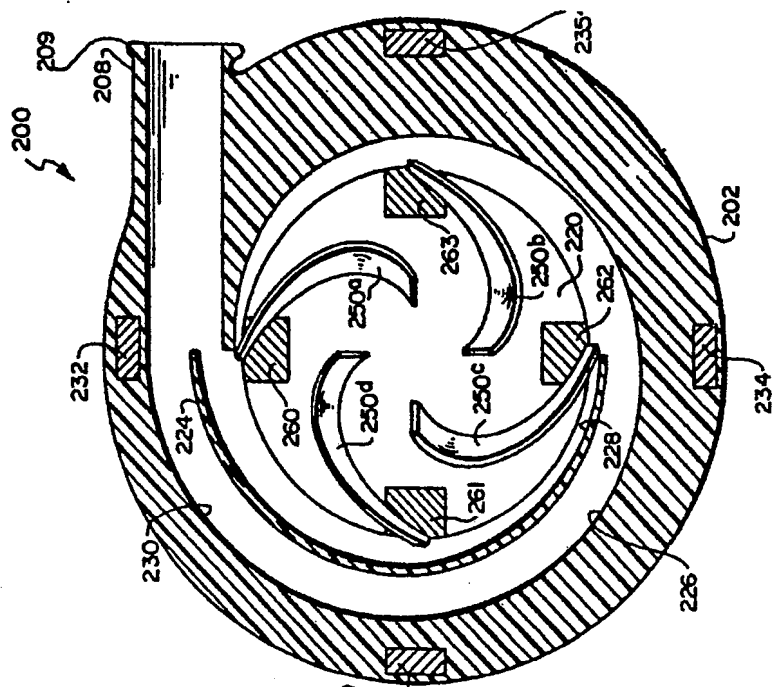


Fig. 9

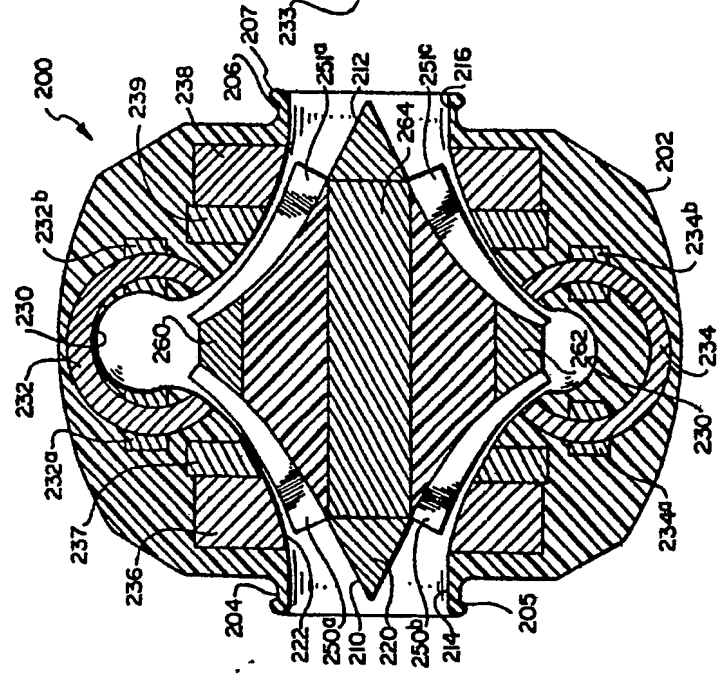


Fig. 8

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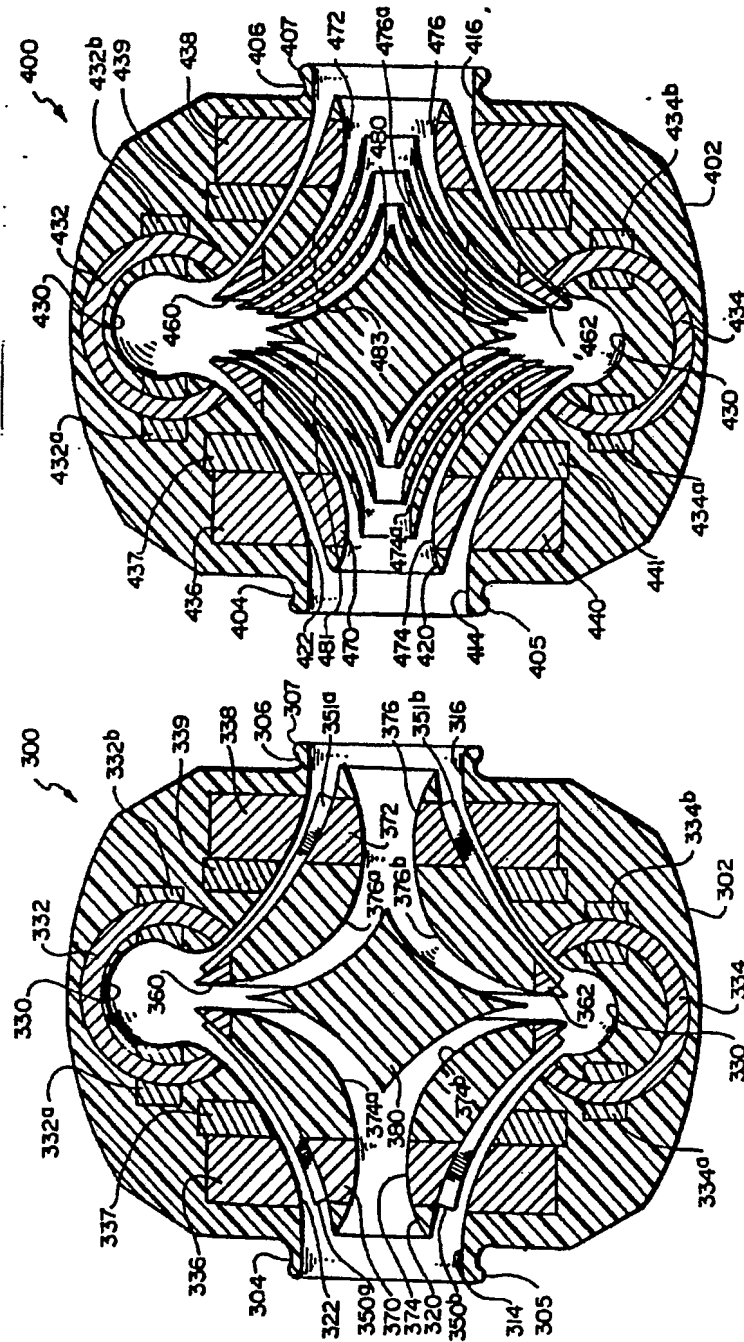


Fig. 11

Fig. 10

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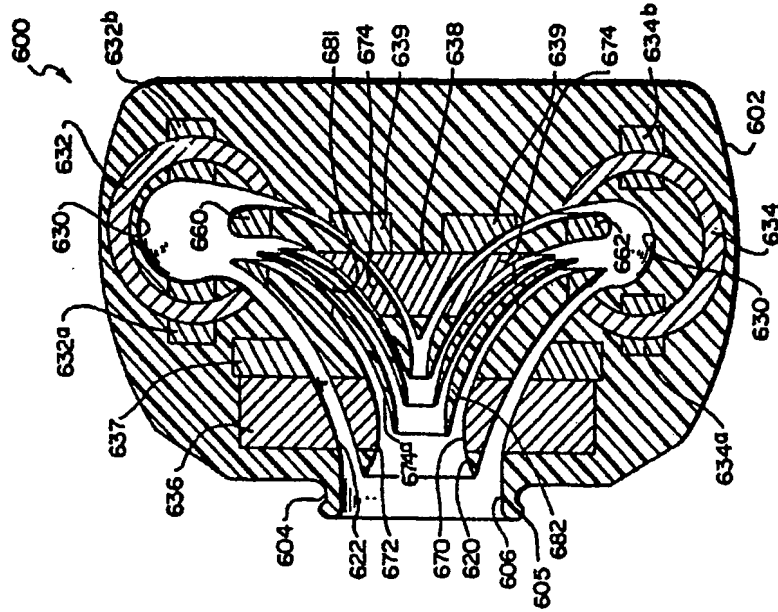


Fig. 12

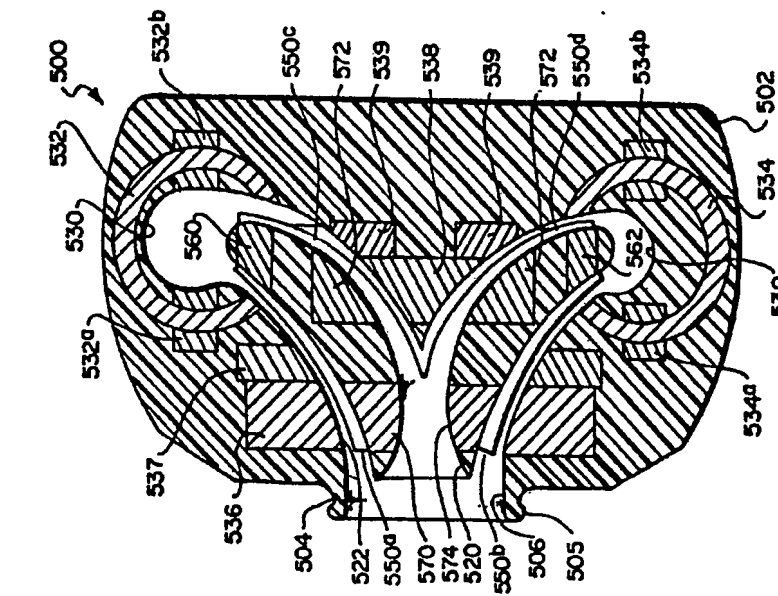


Fig. 13



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EUROPEAN SEARCH REPORT

0060569
Application number

EP 82 10 2188

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	US-A-3 957 389 (RAFFERTY et al.) * column 8, lines 1-33; figure 6 *	1,2,5, 8,18, 21,23, 27	A 61 M 1/03 F 04 D 13/02 H 02 K 7/09
X	FR-A-2 293 623 (TELDIX GmbH) * page 5, line 20 - page 8, line 9; figure * & US - A - 4 082 376	1,2,7, 8,17, 18,19, 20,21, 23,28, 29	
A,D	US-A-3 647 324 (RAFFERTY et al.) * column 3, line 34 - column 7, line 65; figures 1-15 *	1,2,5, 7,8,13, 14,15, 16,21	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	DE-B-1 202 392 (SULZER) * column 3, line 31 - column 5, line 6; figures 1,2 *	1,2,5, 7,8,9, 13,14, 18,21	F 04 D A 61 M H 02 K
A	US-A-3 867 655 (STENGEL et al.) * column 2, line 8 - column 3, line 65; figure 1 *	1,2,3, 8,9	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11-06-1982	Examiner WENZEL A.R.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	



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DOCUMENTS CONSIDERED TO BE RELEVANT			Page 2
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
A	DE-B-1 147 097 (UNITED SHOE MACHINERY CORP.) * column 6, lines 10-43; figures 3,4 *	2,3,8,11	
A	JP-A-53 049 304 (DAINI SEIKOSHA K.K.) * abstract *	1,2,3,8,11,21	
A	US-A-2 629 330 (MELINE) * column 2, line 5 - column 3, line 73; figures 1 to 5 *	2,8,13,14	
A	US-A-1 955 549 (JANETTE) * page 1, lines 73-104; figures 1,3 *	10,12	
A	DE-A-2 510 787 (VAILLANT KG) * page 3, line 26 - page 4, line 3; figures 1-3 *	10,12	TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
A	FR-A-2 177 339 (PADANA AG.) * page 3, line 39 - page 5, line 32; figure 1 *	17,18,19,20	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11-06-1982	Examiner WENZEL A.R.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			